FIG.1

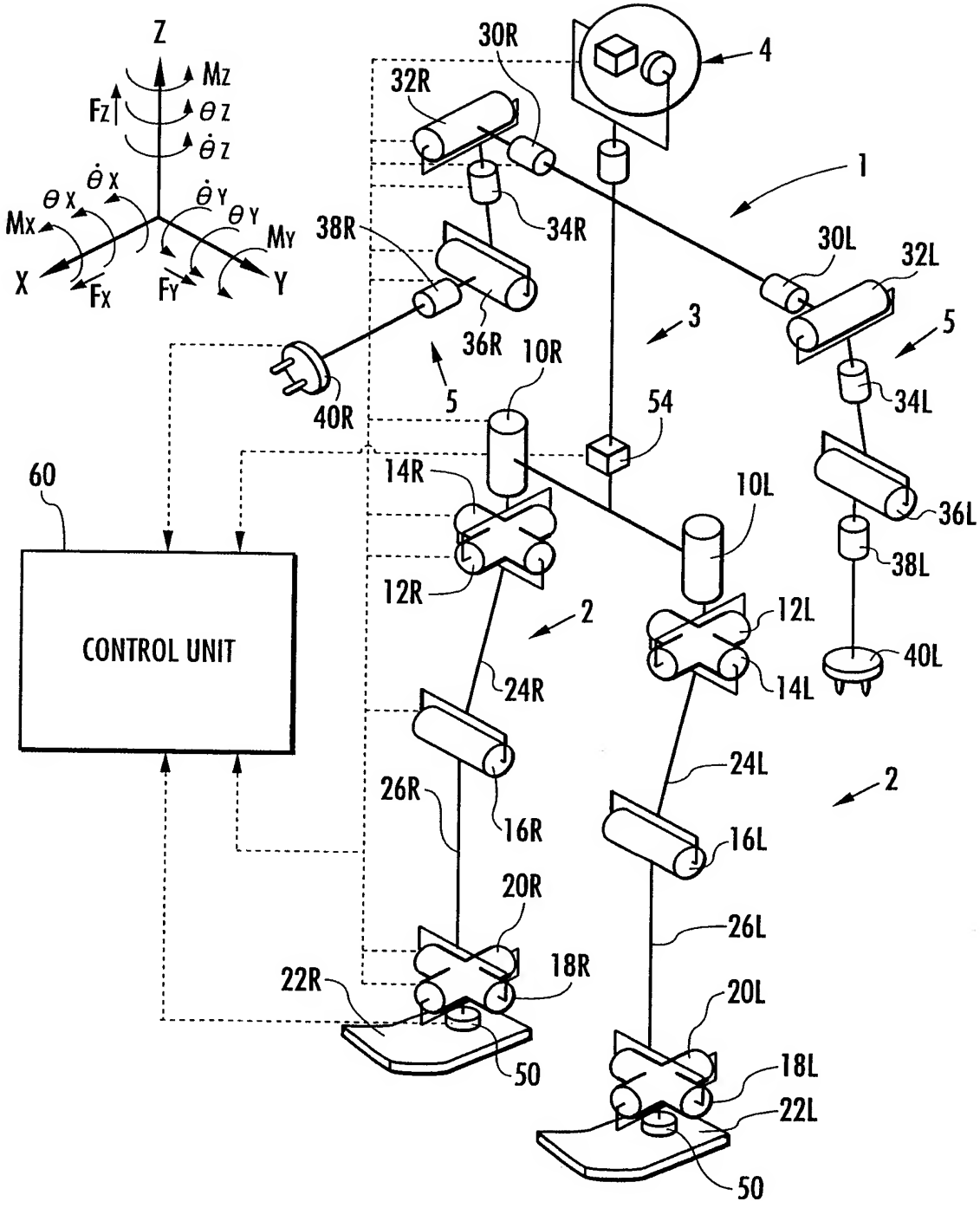

Z
Mz
Fz
θz
θ̇z
θ̇x
θx
θ̇y
θy
Mx
My
X
Y
Fx
Fy
30R
32R
4
1
34R
38R
30L
32L
3
5
36R
10R
5
34L
40R
54
14R
10L
36L
60
38L
12R
12L
2
CONTROL UNIT
40L
24R
14L
24L
2
26R
16R
16L
20R
26L
18R
22R
20L
18L
22L
50
50

FIG.2

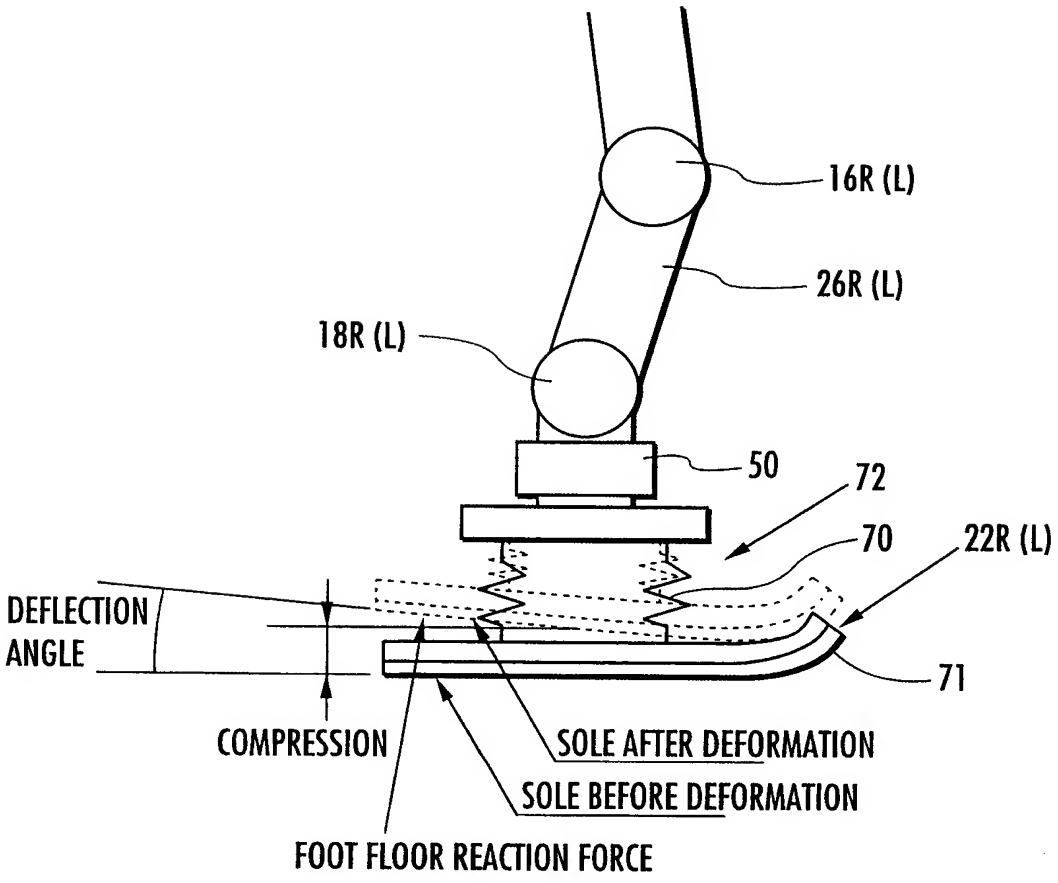

16R (L)
26R (L)
18R (L)
50
72
70
22R (L)
71
DEFLECTION ANGLE
COMPRESSION
SOLE AFTER DEFORMATION
SOLE BEFORE DEFORMATION
FOOT FLOOR REACTION FORCE

FIG.3

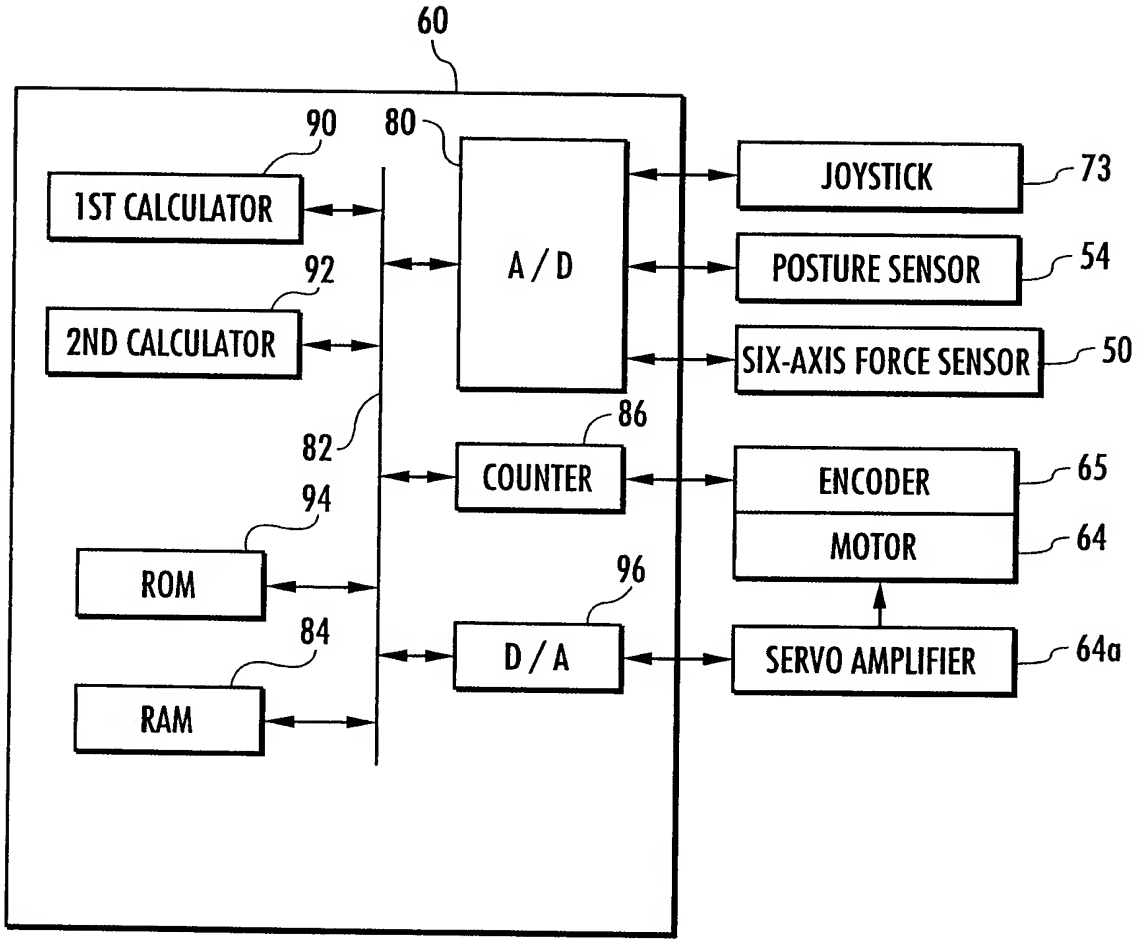

60
90
80
1ST CALCULATOR
A / D
JOYSTICK
73
92
2ND CALCULATOR
POSTURE SENSOR
54
SIX-AXIS FORCE SENSOR
50
82
86
COUNTER
ENCODER
65
94
MOTOR
64
ROM
96
84
D / A
SERVO AMPLIFIER
64a
RAM

FIG.4

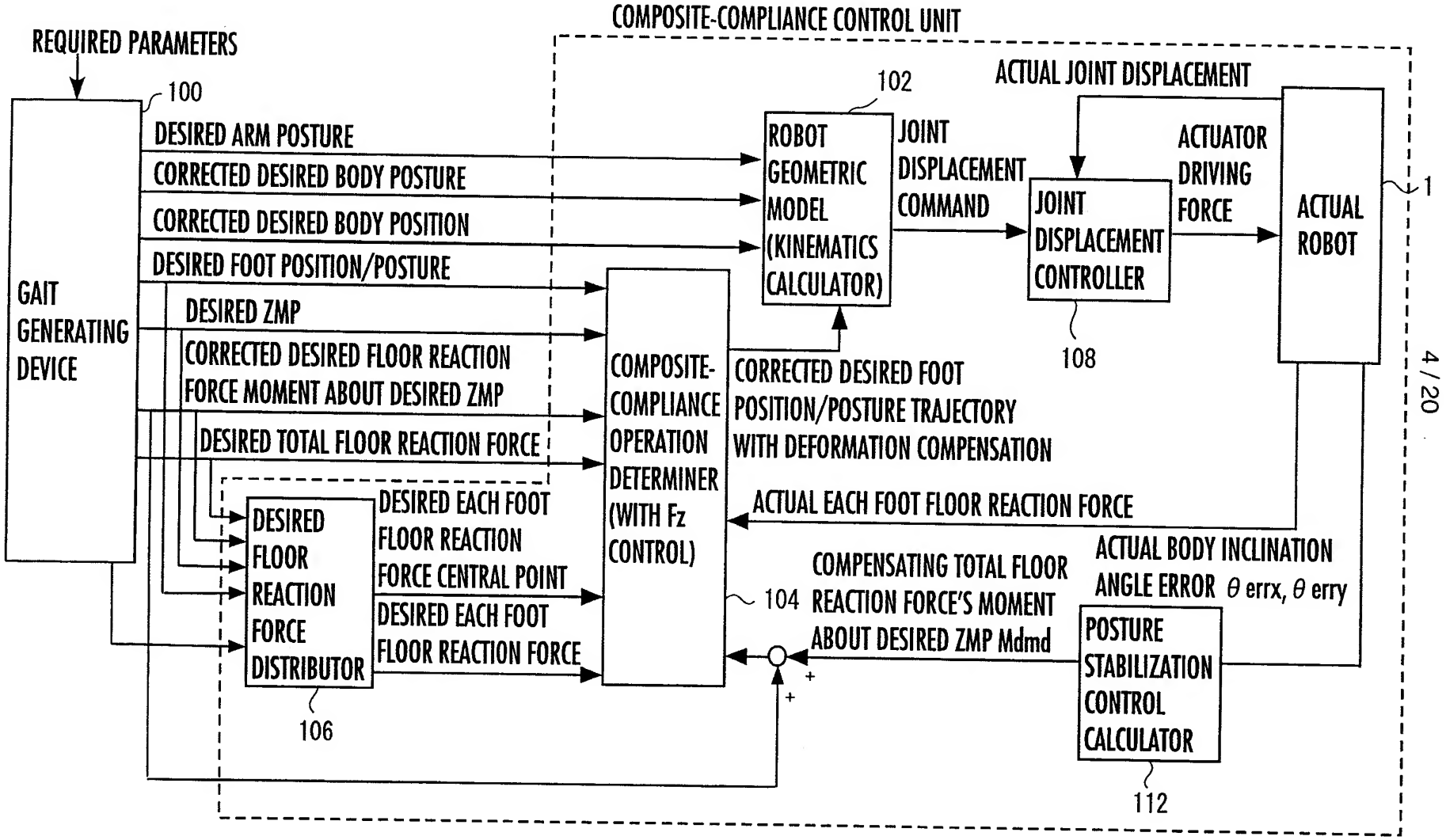

COMPOSITE-COMPLIANCE CONTROL UNIT
REQUIRED PARAMETERS
100
GAIT GENERATING DEVICE
DESIRED ARM POSTURE
CORRECTED DESIRED BODY POSTURE
CORRECTED DESIRED BODY POSITION
DESIRED FOOT POSITION/POSTURE
DESIRED ZMP
CORRECTED DESIRED FLOOR REACTION FORCE MOMENT ABOUT DESIRED ZMP
DESIRED TOTAL FLOOR REACTION FORCE
DESIRED FLOOR REACTION FORCE DISTRIBUTOR
106
DESIRED EACH FOOT FLOOR REACTION FORCE CENTRAL POINT
DESIRED EACH FOOT FLOOR REACTION FORCE
COMPOSITE-COMPLIANCE OPERATION DETERMINER (WITH Fz CONTROL)
104
102
ROBOT GEOMETRIC MODEL (KINEMATICS CALCULATOR)
JOINT DISPLACEMENT COMMAND
ACTUAL JOINT DISPLACEMENT
JOINT DISPLACEMENT CONTROLLER
108
ACTUATOR DRIVING FORCE
ACTUAL ROBOT
1
CORRECTED DESIRED FOOT POSITION/POSTURE TRAJECTORY WITH DEFORMATION COMPENSATION
ACTUAL EACH FOOT FLOOR REACTION FORCE
COMPENSATING TOTAL FLOOR REACTION FORCE'S MOMENT ABOUT DESIRED ZMP Mdmd
ACTUAL BODY INCLINATION ANGLE ERROR θ errx, θ erry
POSTURE STABILIZATION CONTROL CALCULATOR
112
+
+

FIG.5

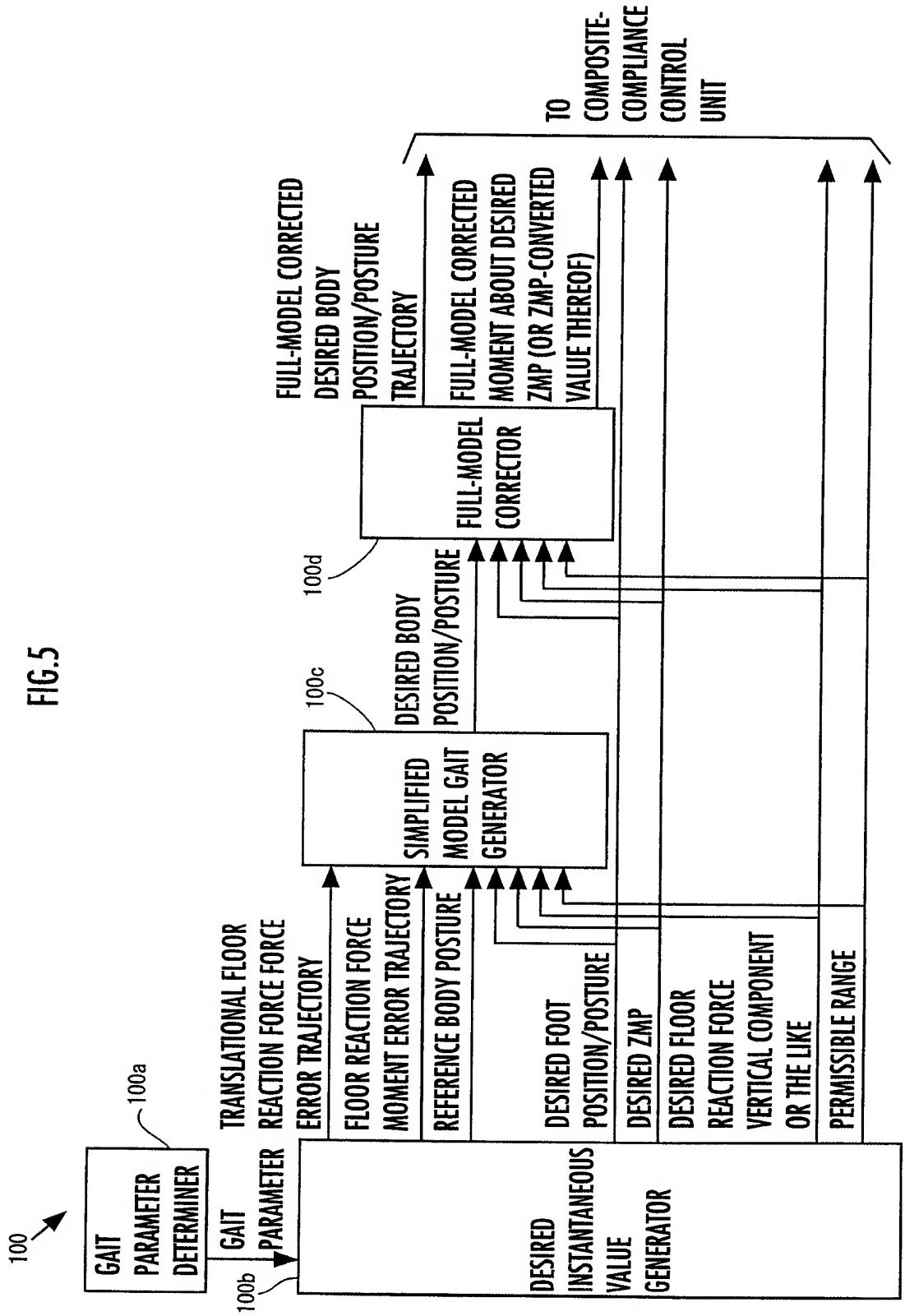

100
GAIT PARAMETER DETERMINER
100a
GAIT PARAMETER
100b
DESIRED INSTANTANEOUS VALUE GENERATOR
TRANSLATIONAL FLOOR REACTION FORCE ERROR TRAJECTORY
FLOOR REACTION FORCE MOMENT ERROR TRAJECTORY
REFERENCE BODY POSTURE
DESIRED FOOT POSITION/POSTURE
DESIRED ZMP
DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT OR THE LIKE
PERMISSIBLE RANGE
SIMPLIFIED MODEL GAIT GENERATOR
100c
DESIRED BODY POSITION/POSTURE
FULL-MODEL CORRECTOR
100d
FULL-MODEL CORRECTED DESIRED BODY POSITION/POSTURE TRAJECTORY
FULL-MODEL CORRECTED MOMENT ABOUT DESIRED ZMP (OR ZMP-CONVERTED VALUE THEREOF)
TO COMPOSITE-COMPLIANCE CONTROL UNIT

FIG.6(a)

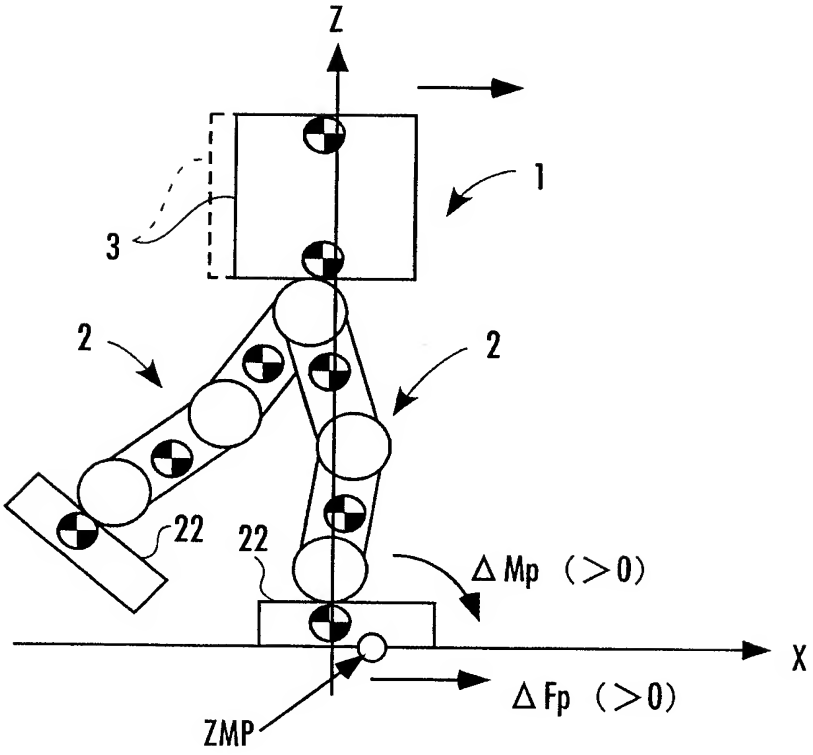

Z
1
3
2
2
22
22
ΔMp (>0)
X
ΔFp (>0)
ZMP

FIG.6(b)

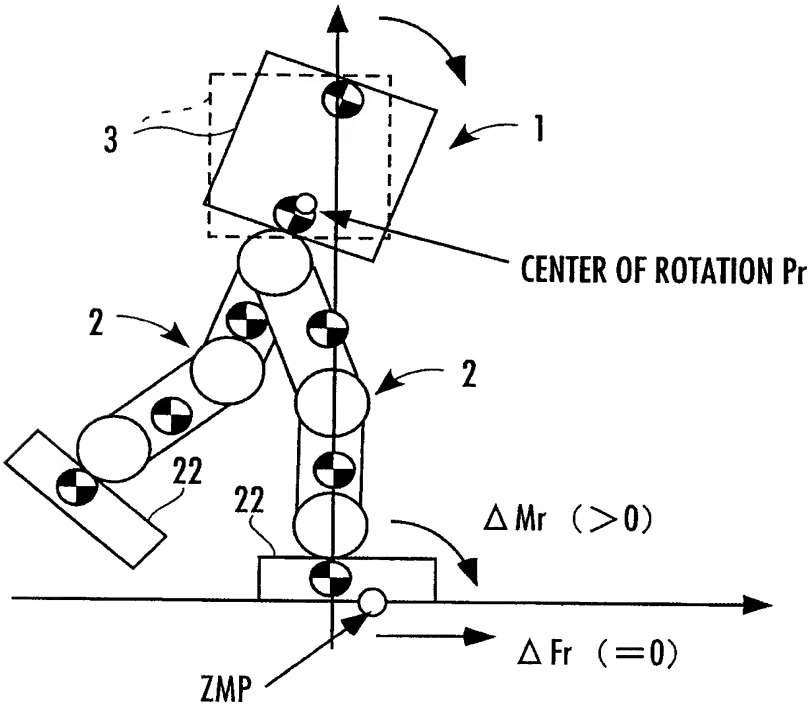

3
1
CENTER OF ROTATION Pr
2
2
22
22
ΔMr (>0)
ΔFr (=0)
ZMP

FIG.7

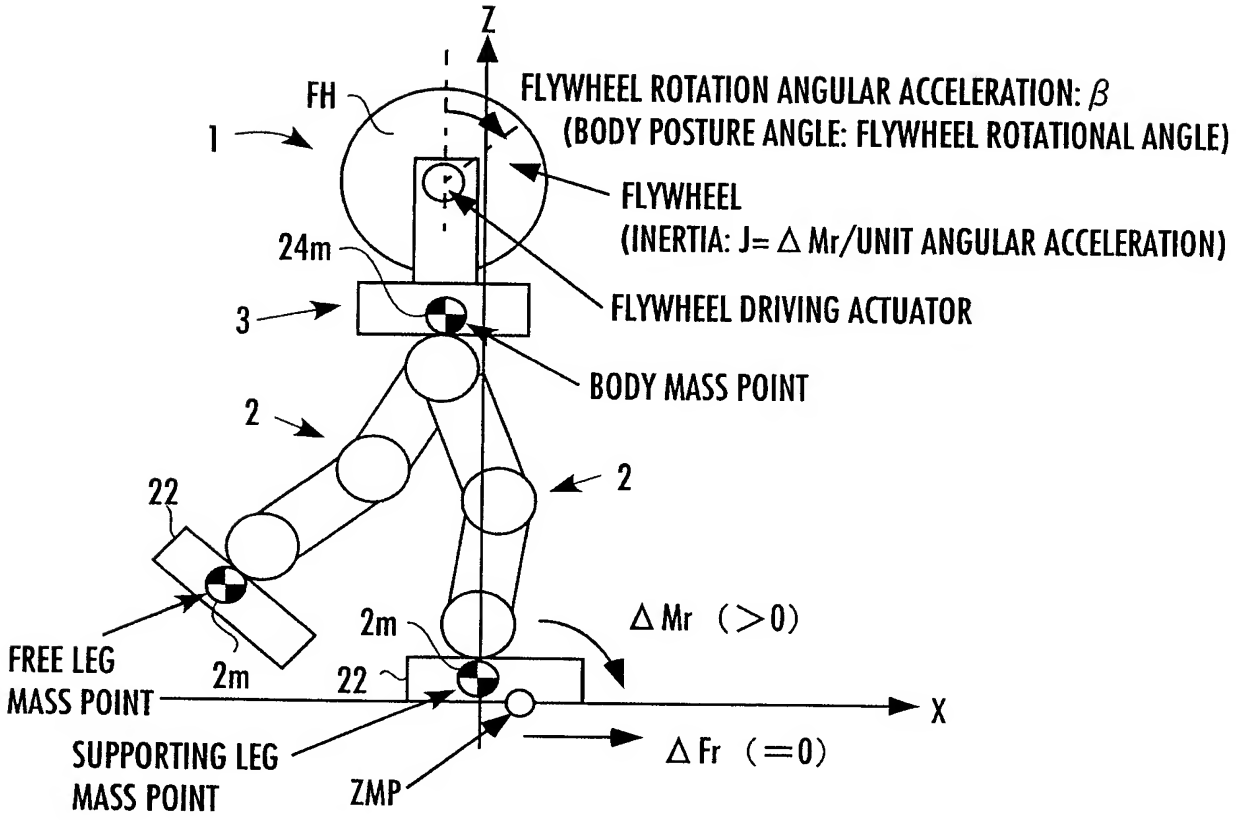

Z
FH
1
FLYWHEEL ROTATION ANGULAR ACCELERATION: β
(BODY POSTURE ANGLE: FLYWHEEL ROTATIONAL ANGLE)
FLYWHEEL
(INERTIA: J= Δ Mr/UNIT ANGULAR ACCELERATION)
24m
3
FLYWHEEL DRIVING ACTUATOR
BODY MASS POINT
2
2
22
2m
Δ Mr (>0)
FREE LEG
MASS POINT
2m
22
X
SUPPORTING LEG
MASS POINT
ZMP
Δ Fr (=0)

FIG.8

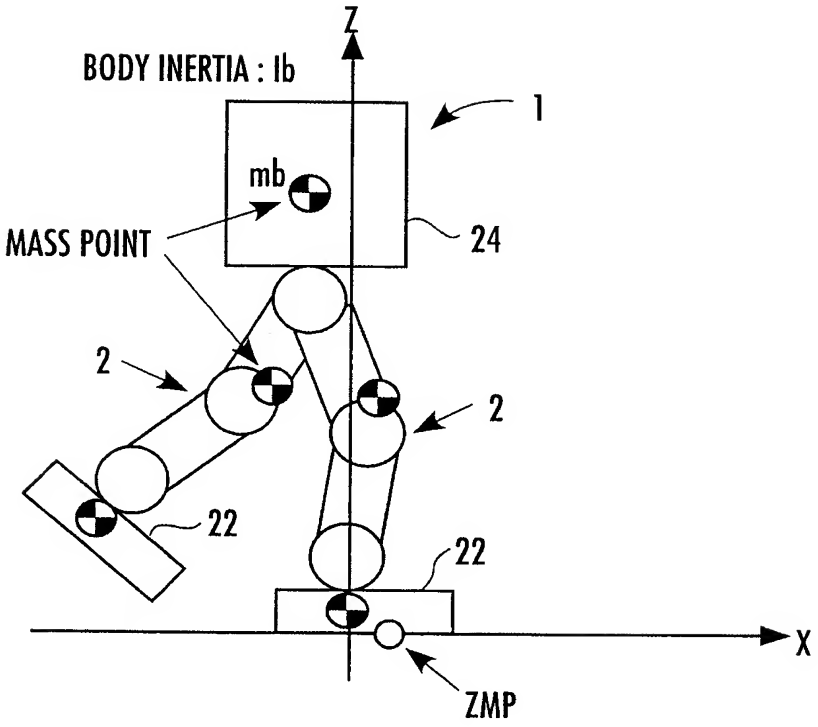


FIG.9

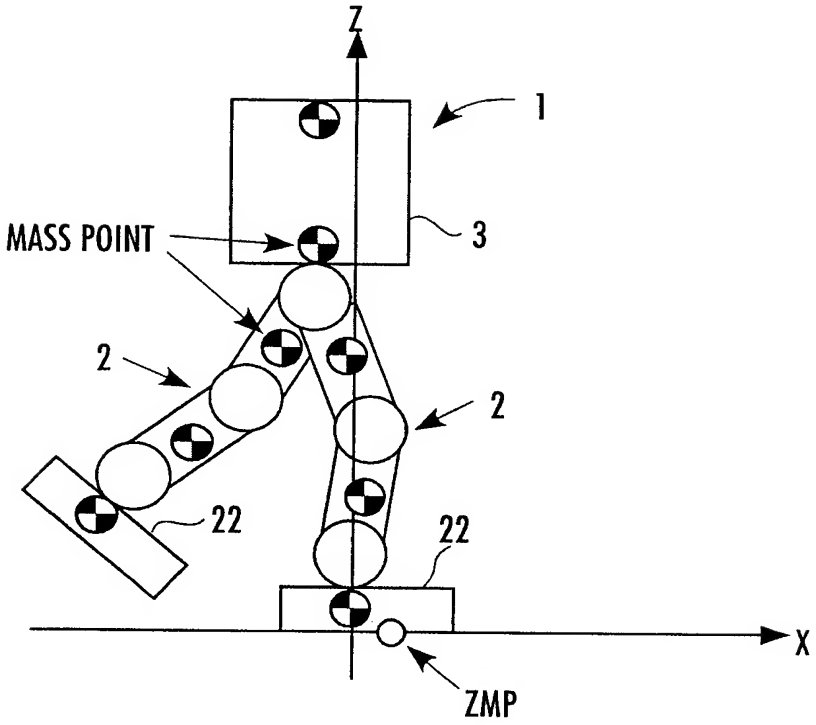


FIG.10

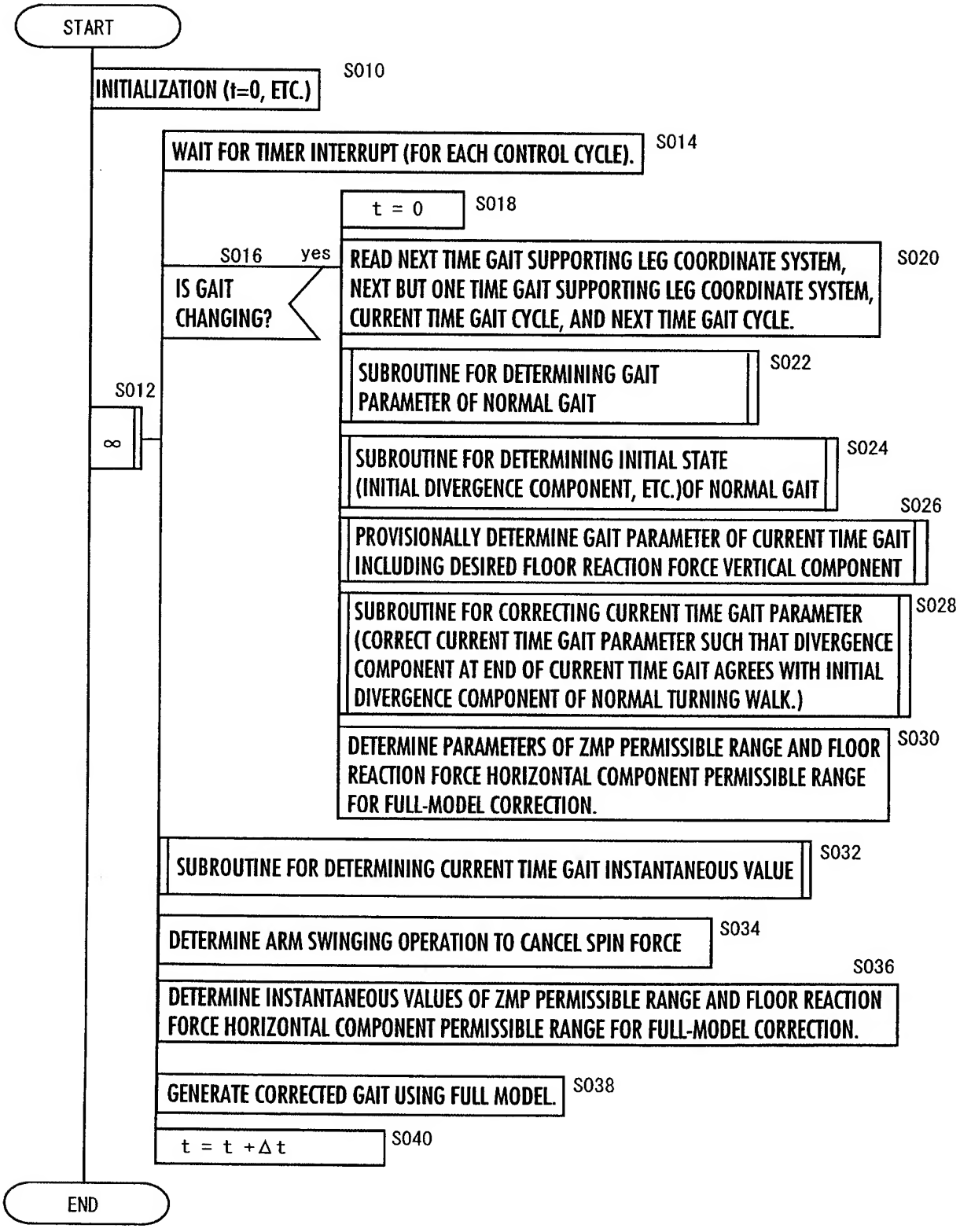

START
INITIALIZATION (t=0, ETC.)
S010
WAIT FOR TIMER INTERRUPT (FOR EACH CONTROL CYCLE).
S014
t = 0
S018
S016
yes
IS GAIT CHANGING?
READ NEXT TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, NEXT BUT ONE TIME GAIT SUPPORTING LEG COORDINATE SYSTEM, CURRENT TIME GAIT CYCLE, AND NEXT TIME GAIT CYCLE.
S020
SUBROUTINE FOR DETERMINING GAIT PARAMETER OF NORMAL GAIT
S022
S012
∞
SUBROUTINE FOR DETERMINING INITIAL STATE (INITIAL DIVERGENCE COMPONENT, ETC.)OF NORMAL GAIT
S024
S026
PROVISIONALLY DETERMINE GAIT PARAMETER OF CURRENT TIME GAIT INCLUDING DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT
SUBROUTINE FOR CORRECTING CURRENT TIME GAIT PARAMETER (CORRECT CURRENT TIME GAIT PARAMETER SUCH THAT DIVERGENCE COMPONENT AT END OF CURRENT TIME GAIT AGREES WITH INITIAL DIVERGENCE COMPONENT OF NORMAL TURNING WALK.)
S028
DETERMINE PARAMETERS OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
S030
SUBROUTINE FOR DETERMINING CURRENT TIME GAIT INSTANTANEOUS VALUE
S032
DETERMINE ARM SWINGING OPERATION TO CANCEL SPIN FORCE
S034
S036
DETERMINE INSTANTANEOUS VALUES OF ZMP PERMISSIBLE RANGE AND FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE FOR FULL-MODEL CORRECTION.
GENERATE CORRECTED GAIT USING FULL MODEL.
S038
t = t +Δt
S040
END

FIG.11

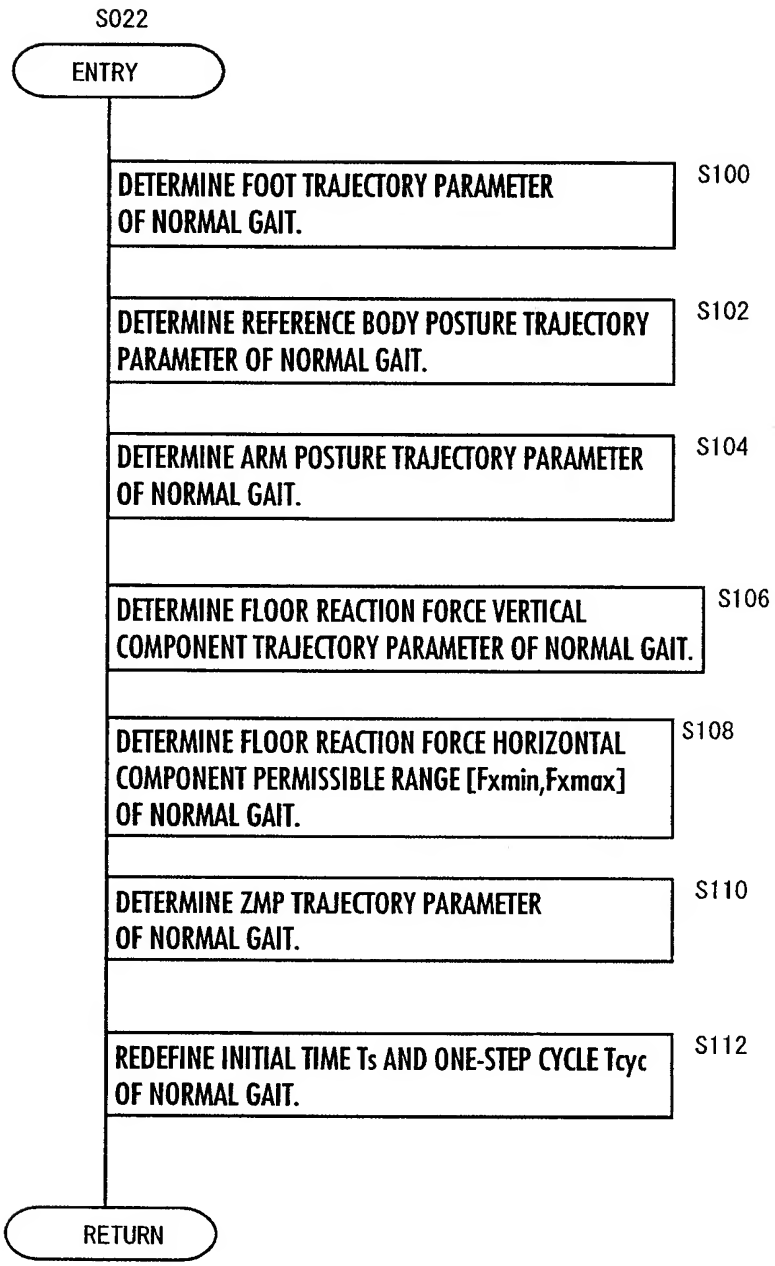

S022
ENTRY
DETERMINE FOOT TRAJECTORY PARAMETER OF NORMAL GAIT.
S100
DETERMINE REFERENCE BODY POSTURE TRAJECTORY PARAMETER OF NORMAL GAIT.
S102
DETERMINE ARM POSTURE TRAJECTORY PARAMETER OF NORMAL GAIT.
S104
DETERMINE FLOOR REACTION FORCE VERTICAL COMPONENT TRAJECTORY PARAMETER OF NORMAL GAIT.
S106
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE [Fxmin,Fxmax] OF NORMAL GAIT.
S108
DETERMINE ZMP TRAJECTORY PARAMETER OF NORMAL GAIT.
S110
REDEFINE INITIAL TIME Ts AND ONE-STEP CYCLE Tcyc OF NORMAL GAIT.
S112
RETURN

FIG.12

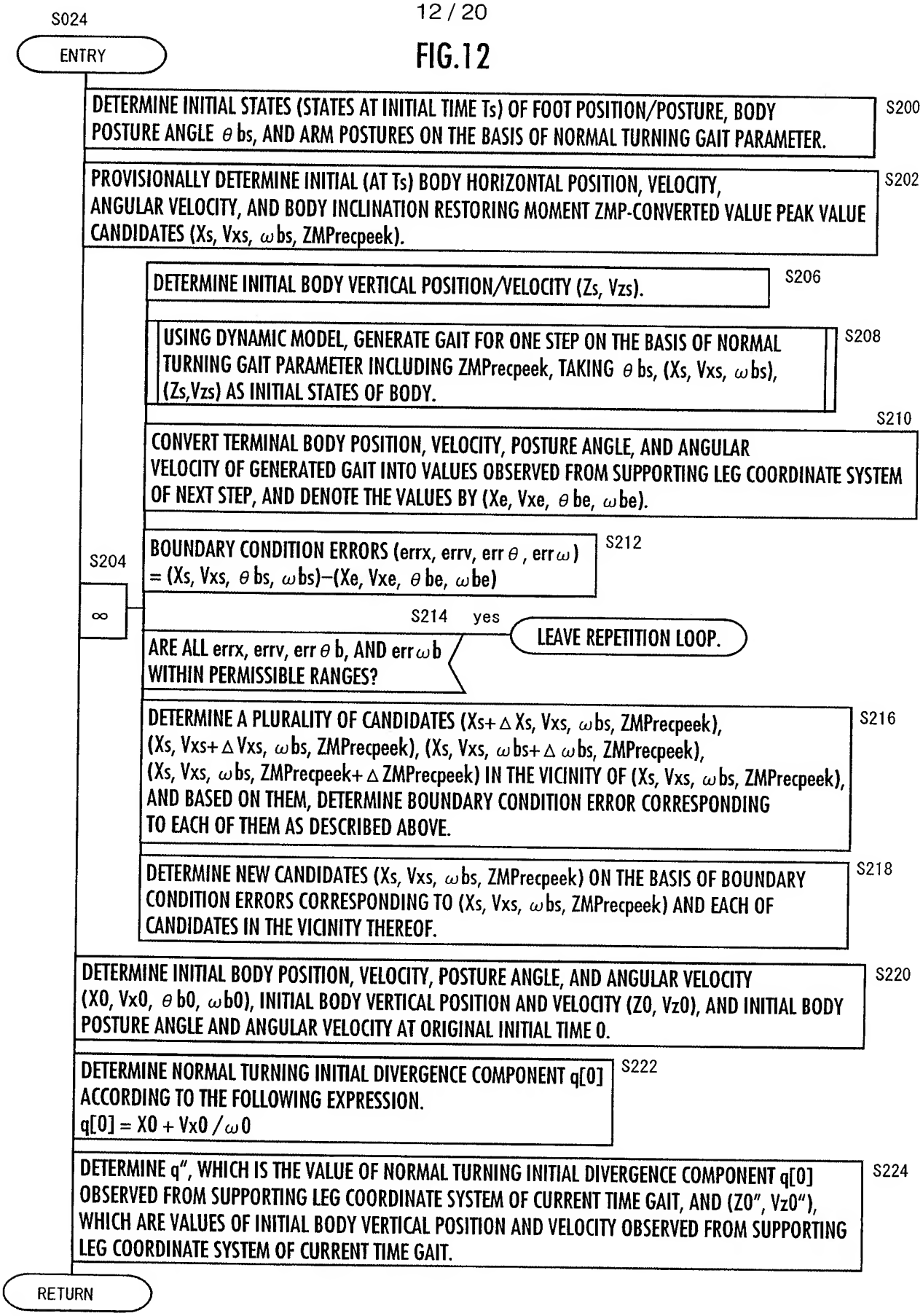

S024
ENTRY
DETERMINE INITIAL STATES (STATES AT INITIAL TIME Ts) OF FOOT POSITION/POSTURE, BODY POSTURE ANGLE θbs, AND ARM POSTURES ON THE BASIS OF NORMAL TURNING GAIT PARAMETER.
S200
PROVISIONALLY DETERMINE INITIAL (AT Ts) BODY HORIZONTAL POSITION, VELOCITY, ANGULAR VELOCITY, AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (Xs, Vxs, ωbs, ZMPrecpeek).
S202
DETERMINE INITIAL BODY VERTICAL POSITION/VELOCITY (Zs, Vzs).
S206
USING DYNAMIC MODEL, GENERATE GAIT FOR ONE STEP ON THE BASIS OF NORMAL TURNING GAIT PARAMETER INCLUDING ZMPrecpeek, TAKING θbs, (Xs, Vxs, ωbs), (Zs,Vzs) AS INITIAL STATES OF BODY.
S208
CONVERT TERMINAL BODY POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY OF GENERATED GAIT INTO VALUES OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF NEXT STEP, AND DENOTE THE VALUES BY (Xe, Vxe, θbe, ωbe).
S210
BOUNDARY CONDITION ERRORS (errx, errv, errθ, errω) = (Xs, Vxs, θbs, ωbs)−(Xe, Vxe, θbe, ωbe)
S212
S204
∞
ARE ALL errx, errv, errθb, AND errωb WITHIN PERMISSIBLE RANGES?
S214
yes
LEAVE REPETITION LOOP.
DETERMINE A PLURALITY OF CANDIDATES (Xs+ΔXs, Vxs, ωbs, ZMPrecpeek), (Xs, Vxs+ΔVxs, ωbs, ZMPrecpeek), (Xs, Vxs, ωbs+Δωbs, ZMPrecpeek), (Xs, Vxs, ωbs, ZMPrecpeek+ΔZMPrecpeek) IN THE VICINITY OF (Xs, Vxs, ωbs, ZMPrecpeek), AND BASED ON THEM, DETERMINE BOUNDARY CONDITION ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S216
DETERMINE NEW CANDIDATES (Xs, Vxs, ωbs, ZMPrecpeek) ON THE BASIS OF BOUNDARY CONDITION ERRORS CORRESPONDING TO (Xs, Vxs, ωbs, ZMPrecpeek) AND EACH OF CANDIDATES IN THE VICINITY THEREOF.
S218
DETERMINE INITIAL BODY POSITION, VELOCITY, POSTURE ANGLE, AND ANGULAR VELOCITY (X0, Vx0, θb0, ωb0), INITIAL BODY VERTICAL POSITION AND VELOCITY (Z0, Vz0), AND INITIAL BODY POSTURE ANGLE AND ANGULAR VELOCITY AT ORIGINAL INITIAL TIME 0.
S220
DETERMINE NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] ACCORDING TO THE FOLLOWING EXPRESSION.
q[0] = X0 + Vx0 / ω0
S222
DETERMINE q'', WHICH IS THE VALUE OF NORMAL TURNING INITIAL DIVERGENCE COMPONENT q[0] OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME GAIT, AND (Z0'', Vz0''), WHICH ARE VALUES OF INITIAL BODY VERTICAL POSITION AND VELOCITY OBSERVED FROM SUPPORTING LEG COORDINATE SYSTEM OF CURRENT TIME GAIT.
S224
RETURN

FIG.13

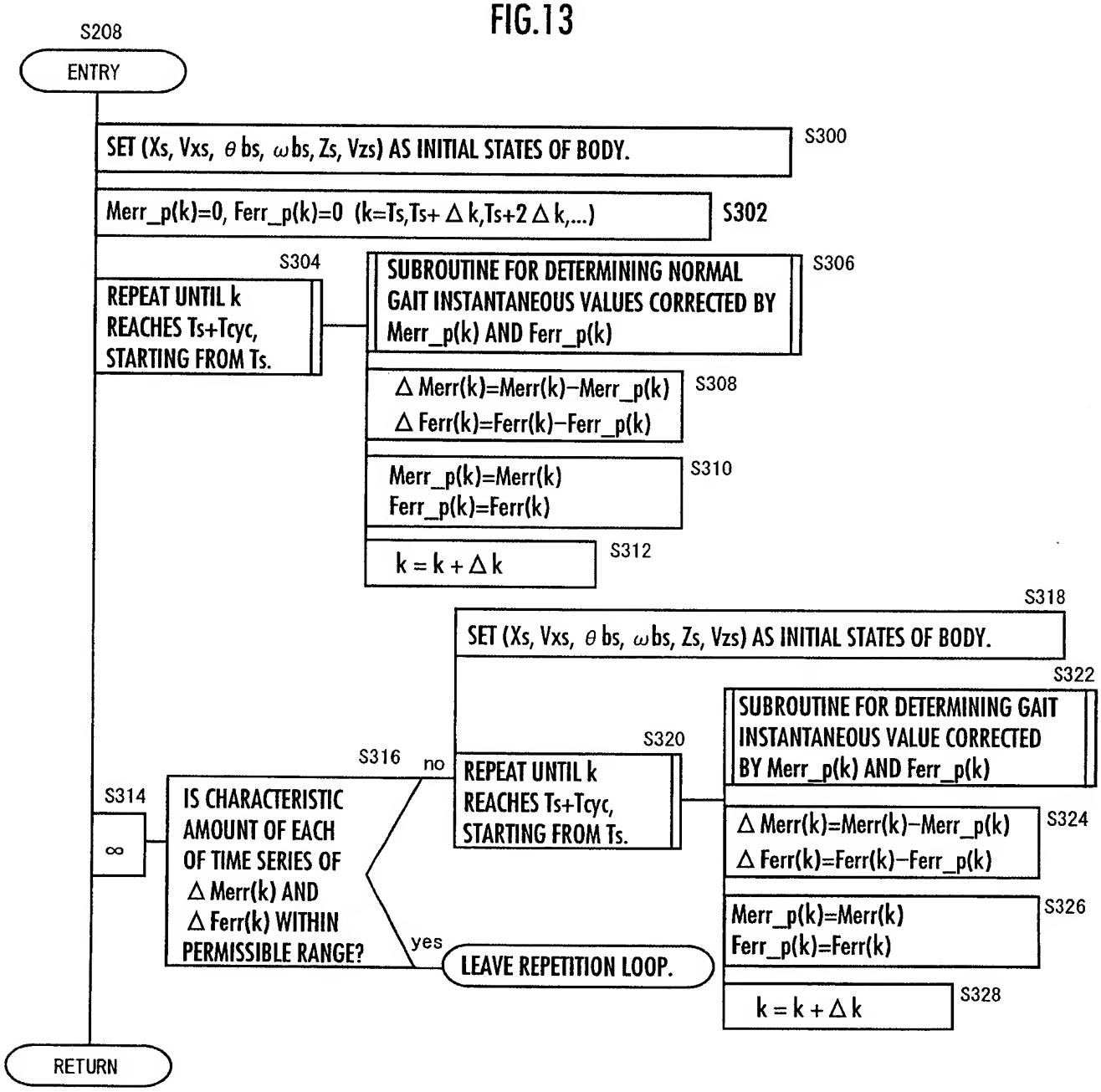

S208
ENTRY
SET (Xs, Vxs, θbs, ωbs, Zs, Vzs) AS INITIAL STATES OF BODY.
S300
Merr_p(k)=0, Ferr_p(k)=0 (k=Ts,Ts+Δk,Ts+2Δk,...)
S302
S304
REPEAT UNTIL k REACHES Ts+Tcyc, STARTING FROM Ts.
SUBROUTINE FOR DETERMINING NORMAL GAIT INSTANTANEOUS VALUES CORRECTED BY Merr_p(k) AND Ferr_p(k)
S306
Δ Merr(k)=Merr(k)−Merr_p(k)
Δ Ferr(k)=Ferr(k)−Ferr_p(k)
S308
Merr_p(k)=Merr(k)
Ferr_p(k)=Ferr(k)
S310
k = k + Δk
S312
S318
SET (Xs, Vxs, θbs, ωbs, Zs, Vzs) AS INITIAL STATES OF BODY.
S322
SUBROUTINE FOR DETERMINING GAIT INSTANTANEOUS VALUE CORRECTED BY Merr_p(k) AND Ferr_p(k)
S320
S316
no
REPEAT UNTIL k REACHES Ts+Tcyc, STARTING FROM Ts.
S314
∞
IS CHARACTERISTIC AMOUNT OF EACH OF TIME SERIES OF Δ Merr(k) AND Δ Ferr(k) WITHIN PERMISSIBLE RANGE?
yes
LEAVE REPETITION LOOP.
Δ Merr(k)=Merr(k)−Merr_p(k)
Δ Ferr(k)=Ferr(k)−Ferr_p(k)
S324
Merr_p(k)=Merr(k)
Ferr_p(k)=Ferr(k)
S326
k = k + Δk
S328
RETURN

FIG.14

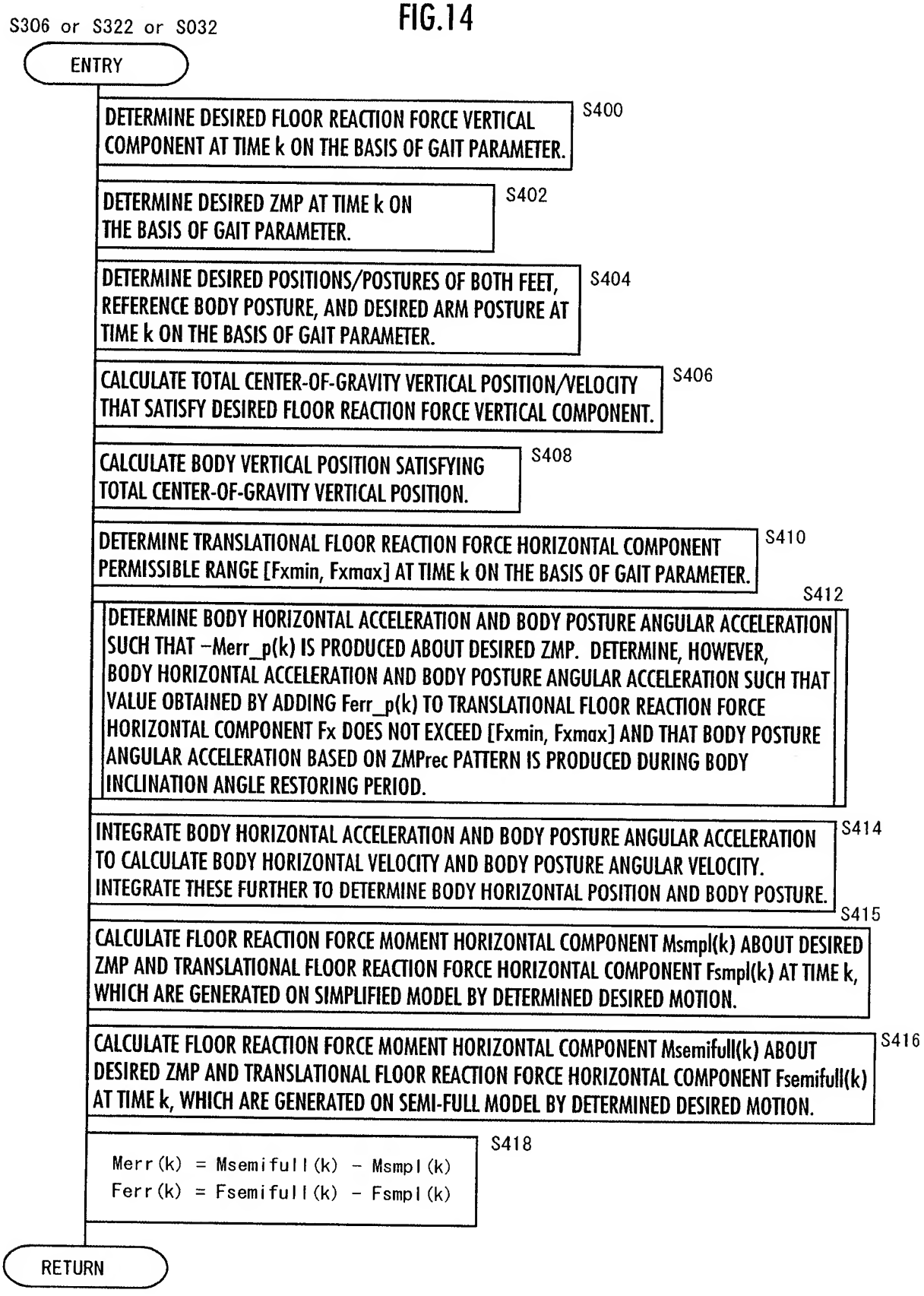

S306 or S322 or S032
ENTRY
DETERMINE DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT AT TIME k ON THE BASIS OF GAIT PARAMETER.
S400
DETERMINE DESIRED ZMP AT TIME k ON THE BASIS OF GAIT PARAMETER.
S402
DETERMINE DESIRED POSITIONS/POSTURES OF BOTH FEET, REFERENCE BODY POSTURE, AND DESIRED ARM POSTURE AT TIME k ON THE BASIS OF GAIT PARAMETER.
S404
CALCULATE TOTAL CENTER-OF-GRAVITY VERTICAL POSITION/VELOCITY THAT SATISFY DESIRED FLOOR REACTION FORCE VERTICAL COMPONENT.
S406
CALCULATE BODY VERTICAL POSITION SATISFYING TOTAL CENTER-OF-GRAVITY VERTICAL POSITION.
S408
DETERMINE TRANSLATIONAL FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE [Fxmin, Fxmax] AT TIME k ON THE BASIS OF GAIT PARAMETER.
S410
S412
DETERMINE BODY HORIZONTAL ACCELERATION AND BODY POSTURE ANGULAR ACCELERATION SUCH THAT −Merr_p(k) IS PRODUCED ABOUT DESIRED ZMP. DETERMINE, HOWEVER, BODY HORIZONTAL ACCELERATION AND BODY POSTURE ANGULAR ACCELERATION SUCH THAT VALUE OBTAINED BY ADDING Ferr_p(k) TO TRANSLATIONAL FLOOR REACTION FORCE HORIZONTAL COMPONENT Fx DOES NOT EXCEED [Fxmin, Fxmax] AND THAT BODY POSTURE ANGULAR ACCELERATION BASED ON ZMPrec PATTERN IS PRODUCED DURING BODY INCLINATION ANGLE RESTORING PERIOD.
INTEGRATE BODY HORIZONTAL ACCELERATION AND BODY POSTURE ANGULAR ACCELERATION TO CALCULATE BODY HORIZONTAL VELOCITY AND BODY POSTURE ANGULAR VELOCITY. INTEGRATE THESE FURTHER TO DETERMINE BODY HORIZONTAL POSITION AND BODY POSTURE.
S414
S415
CALCULATE FLOOR REACTION FORCE MOMENT HORIZONTAL COMPONENT Msmpl(k) ABOUT DESIRED ZMP AND TRANSLATIONAL FLOOR REACTION FORCE HORIZONTAL COMPONENT Fsmpl(k) AT TIME k, WHICH ARE GENERATED ON SIMPLIFIED MODEL BY DETERMINED DESIRED MOTION.
CALCULATE FLOOR REACTION FORCE MOMENT HORIZONTAL COMPONENT Msemifull(k) ABOUT DESIRED ZMP AND TRANSLATIONAL FLOOR REACTION FORCE HORIZONTAL COMPONENT Fsemifull(k) AT TIME k, WHICH ARE GENERATED ON SEMI-FULL MODEL BY DETERMINED DESIRED MOTION.
S416
Merr(k) = Msemifull(k) - Msmpl(k)
Ferr(k) = Fsemifull(k) - Fsmpl(k)
S418
RETURN

FIG.15

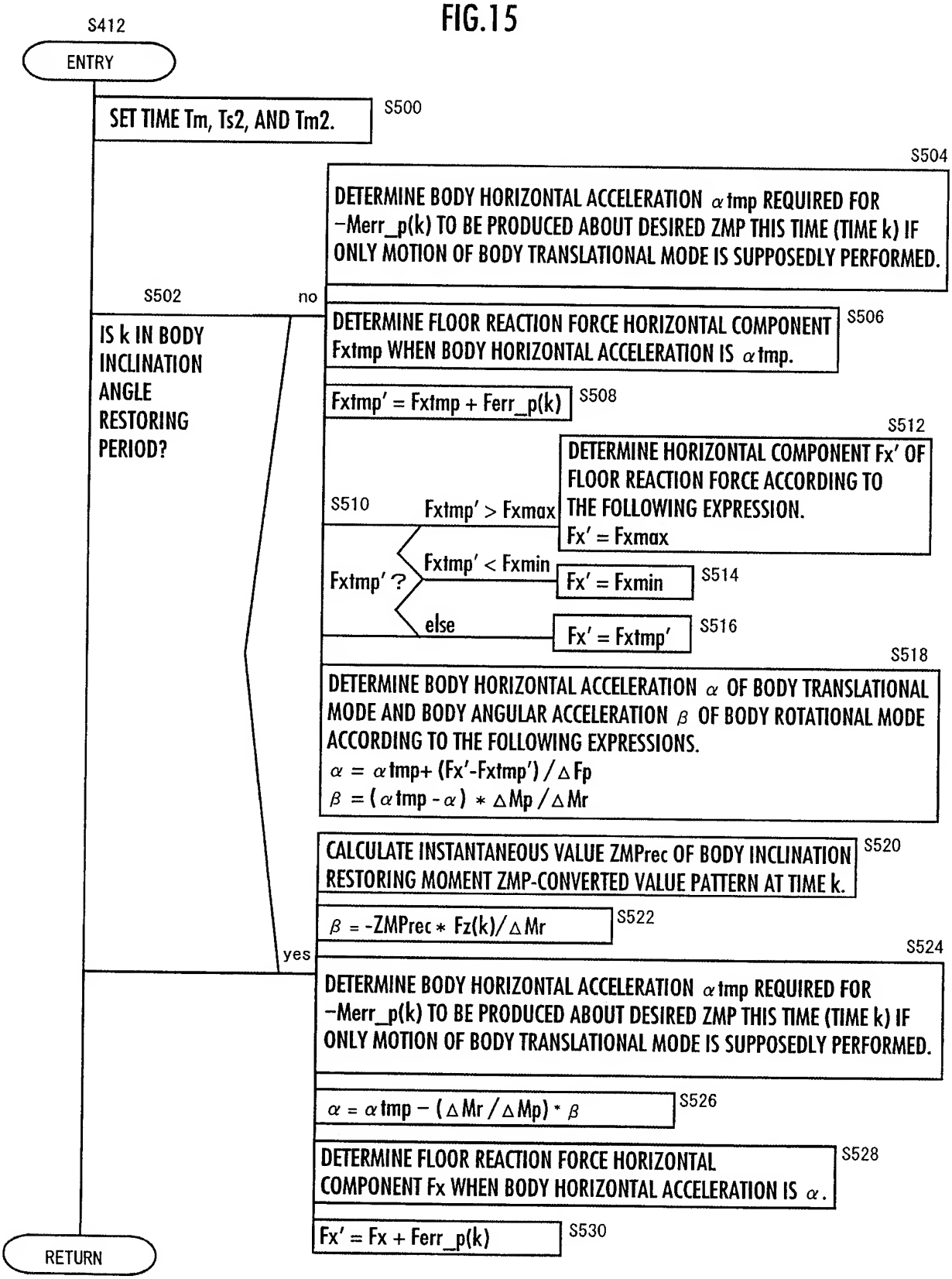

S412
ENTRY
SET TIME Tm, Ts2, AND Tm2.
S500
S502
IS k IN BODY INCLINATION ANGLE RESTORING PERIOD?
no
yes
S504
DETERMINE BODY HORIZONTAL ACCELERATION αtmp REQUIRED FOR −Merr_p(k) TO BE PRODUCED ABOUT DESIRED ZMP THIS TIME (TIME k) IF ONLY MOTION OF BODY TRANSLATIONAL MODE IS SUPPOSEDLY PERFORMED.
S506
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT Fxtmp WHEN BODY HORIZONTAL ACCELERATION IS αtmp.
S508
Fxtmp' = Fxtmp + Ferr_p(k)
S510
Fxtmp' ?
Fxtmp' > Fxmax
S512
DETERMINE HORIZONTAL COMPONENT Fx' OF FLOOR REACTION FORCE ACCORDING TO THE FOLLOWING EXPRESSION.
Fx' = Fxmax
Fxtmp' < Fxmin
Fx' = Fxmin
S514
else
Fx' = Fxtmp'
S516
S518
DETERMINE BODY HORIZONTAL ACCELERATION α OF BODY TRANSLATIONAL MODE AND BODY ANGULAR ACCELERATION β OF BODY ROTATIONAL MODE ACCORDING TO THE FOLLOWING EXPRESSIONS.
α = αtmp+ (Fx'-Fxtmp') / ΔFp
β = (αtmp - α) * ΔMp / ΔMr
S520
CALCULATE INSTANTANEOUS VALUE ZMPrec OF BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PATTERN AT TIME k.
S522
β = -ZMPrec * Fz(k)/ΔMr
S524
DETERMINE BODY HORIZONTAL ACCELERATION αtmp REQUIRED FOR −Merr_p(k) TO BE PRODUCED ABOUT DESIRED ZMP THIS TIME (TIME k) IF ONLY MOTION OF BODY TRANSLATIONAL MODE IS SUPPOSEDLY PERFORMED.
S526
α = αtmp − (ΔMr / ΔMp) * β
S528
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT Fx WHEN BODY HORIZONTAL ACCELERATION IS α.
S530
Fx' = Fx + Ferr_p(k)
RETURN

FIG.16

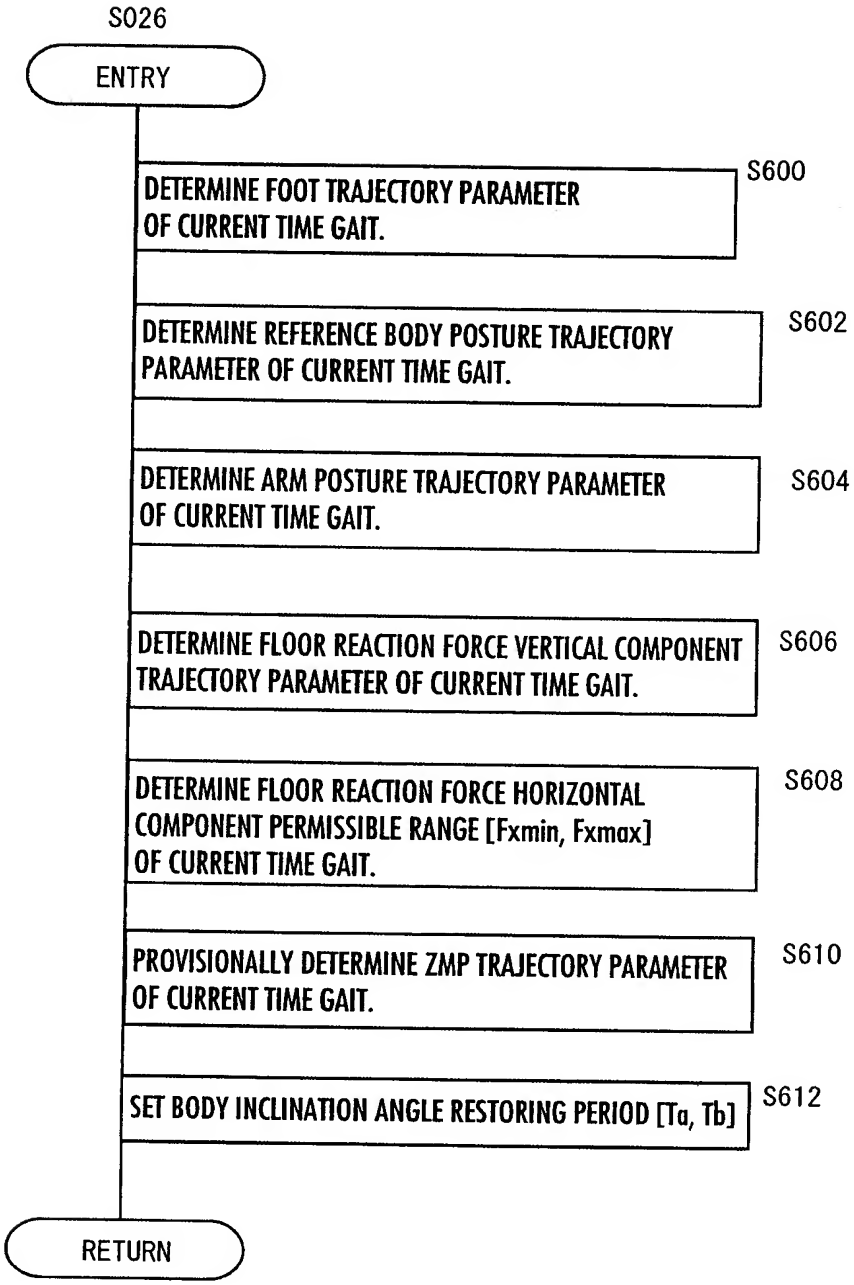

S026
ENTRY
DETERMINE FOOT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S600
DETERMINE REFERENCE BODY POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S602
DETERMINE ARM POSTURE TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S604
DETERMINE FLOOR REACTION FORCE VERTICAL COMPONENT TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S606
DETERMINE FLOOR REACTION FORCE HORIZONTAL COMPONENT PERMISSIBLE RANGE [Fxmin, Fxmax] OF CURRENT TIME GAIT.
S608
PROVISIONALLY DETERMINE ZMP TRAJECTORY PARAMETER OF CURRENT TIME GAIT.
S610
SET BODY INCLINATION ANGLE RESTORING PERIOD [Ta, Tb]
S612
RETURN

FIG.17

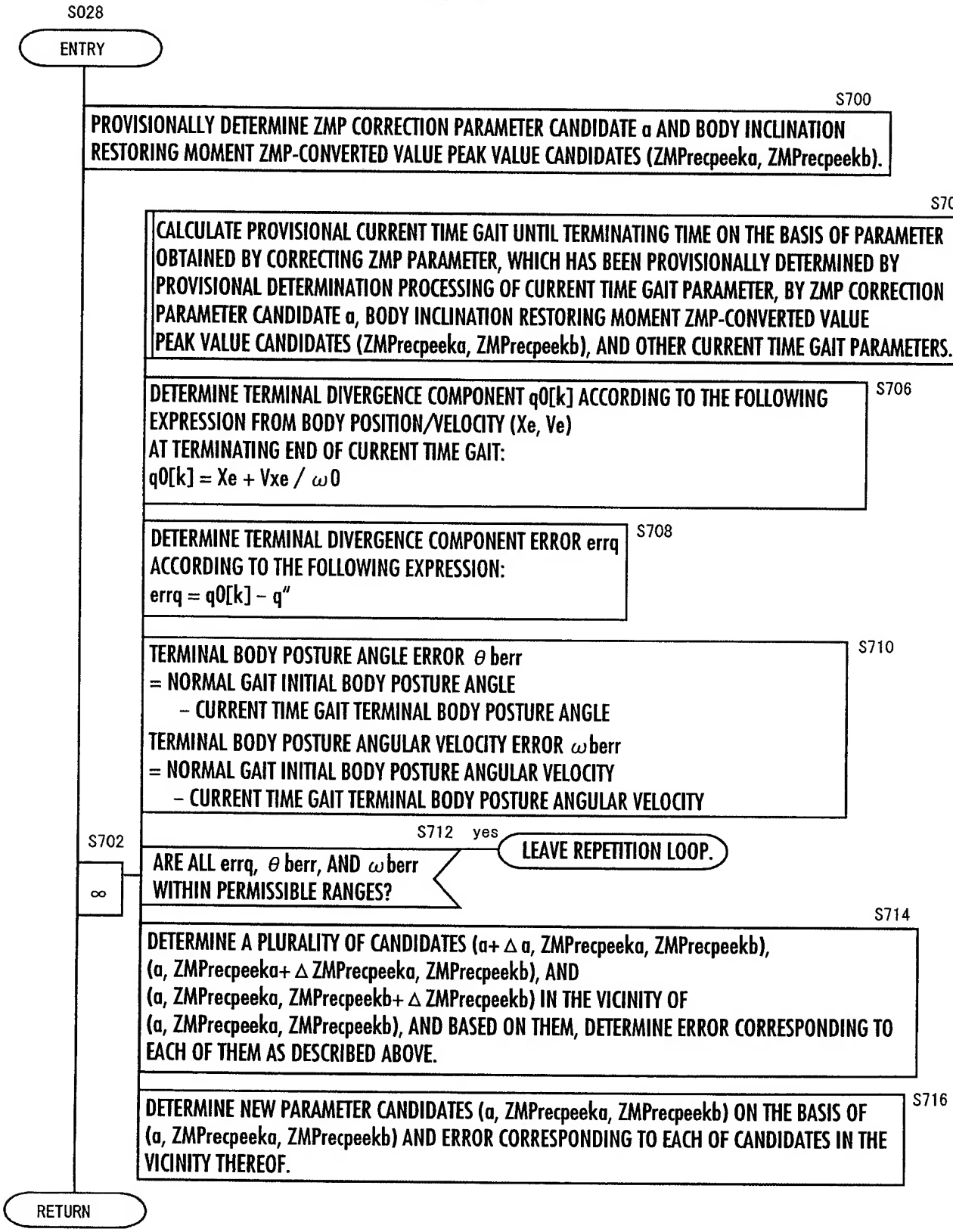

S028
ENTRY
S700
PROVISIONALLY DETERMINE ZMP CORRECTION PARAMETER CANDIDATE a AND BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeeka, ZMPrecpeekb).
S704
CALCULATE PROVISIONAL CURRENT TIME GAIT UNTIL TERMINATING TIME ON THE BASIS OF PARAMETER OBTAINED BY CORRECTING ZMP PARAMETER, WHICH HAS BEEN PROVISIONALLY DETERMINED BY PROVISIONAL DETERMINATION PROCESSING OF CURRENT TIME GAIT PARAMETER, BY ZMP CORRECTION PARAMETER CANDIDATE a, BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE PEAK VALUE CANDIDATES (ZMPrecpeeka, ZMPrecpeekb), AND OTHER CURRENT TIME GAIT PARAMETERS.
S706
DETERMINE TERMINAL DIVERGENCE COMPONENT q0[k] ACCORDING TO THE FOLLOWING EXPRESSION FROM BODY POSITION/VELOCITY (Xe, Ve)
AT TERMINATING END OF CURRENT TIME GAIT:
q0[k] = Xe + Vxe / ω0
S708
DETERMINE TERMINAL DIVERGENCE COMPONENT ERROR errq ACCORDING TO THE FOLLOWING EXPRESSION:
errq = q0[k] − q''
S710
TERMINAL BODY POSTURE ANGLE ERROR θberr
= NORMAL GAIT INITIAL BODY POSTURE ANGLE
− CURRENT TIME GAIT TERMINAL BODY POSTURE ANGLE
TERMINAL BODY POSTURE ANGULAR VELOCITY ERROR ωberr
= NORMAL GAIT INITIAL BODY POSTURE ANGULAR VELOCITY
− CURRENT TIME GAIT TERMINAL BODY POSTURE ANGULAR VELOCITY
S702
∞
S712
yes
ARE ALL errq, θberr, AND ωberr WITHIN PERMISSIBLE RANGES?
LEAVE REPETITION LOOP.
S714
DETERMINE A PLURALITY OF CANDIDATES (a+Δa, ZMPrecpeeka, ZMPrecpeekb), (a, ZMPrecpeeka+ΔZMPrecpeeka, ZMPrecpeekb), AND (a, ZMPrecpeeka, ZMPrecpeekb+ΔZMPrecpeekb) IN THE VICINITY OF (a, ZMPrecpeeka, ZMPrecpeekb), AND BASED ON THEM, DETERMINE ERROR CORRESPONDING TO EACH OF THEM AS DESCRIBED ABOVE.
S716
DETERMINE NEW PARAMETER CANDIDATES (a, ZMPrecpeeka, ZMPrecpeekb) ON THE BASIS OF (a, ZMPrecpeeka, ZMPrecpeekb) AND ERROR CORRESPONDING TO EACH OF CANDIDATES IN THE VICINITY THEREOF.
RETURN

FIG.18

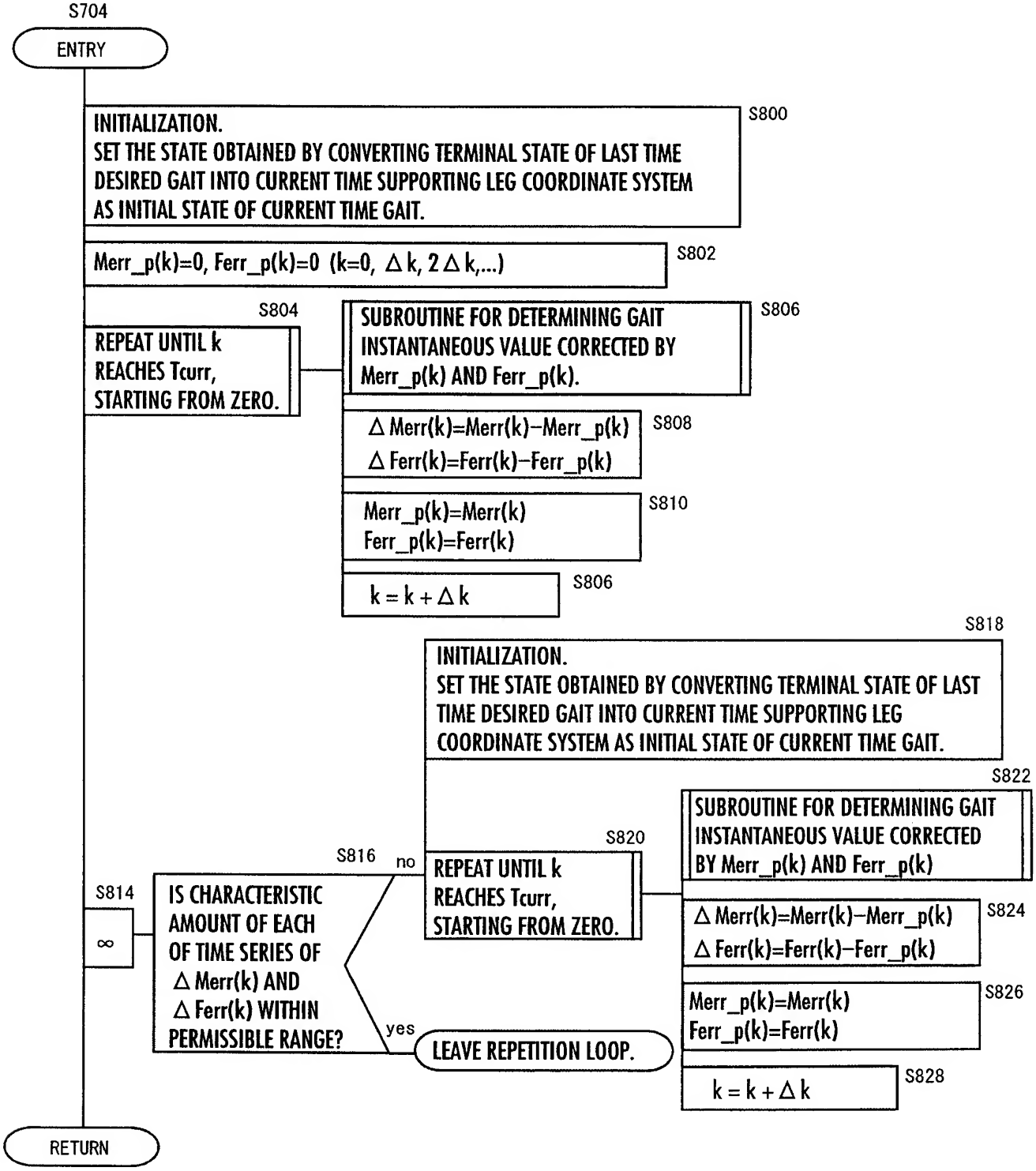

S704
ENTRY
INITIALIZATION.
SET THE STATE OBTAINED BY CONVERTING TERMINAL STATE OF LAST TIME DESIRED GAIT INTO CURRENT TIME SUPPORTING LEG COORDINATE SYSTEM AS INITIAL STATE OF CURRENT TIME GAIT.
S800
Merr_p(k)=0, Ferr_p(k)=0 (k=0, Δk, 2Δk,...)
S802
S804
REPEAT UNTIL k REACHES Tcurr, STARTING FROM ZERO.
SUBROUTINE FOR DETERMINING GAIT INSTANTANEOUS VALUE CORRECTED BY Merr_p(k) AND Ferr_p(k).
S806
ΔMerr(k)=Merr(k)−Merr_p(k)
ΔFerr(k)=Ferr(k)−Ferr_p(k)
S808
Merr_p(k)=Merr(k)
Ferr_p(k)=Ferr(k)
S810
k = k + Δk
S806
S818
INITIALIZATION.
SET THE STATE OBTAINED BY CONVERTING TERMINAL STATE OF LAST TIME DESIRED GAIT INTO CURRENT TIME SUPPORTING LEG COORDINATE SYSTEM AS INITIAL STATE OF CURRENT TIME GAIT.
S822
SUBROUTINE FOR DETERMINING GAIT INSTANTANEOUS VALUE CORRECTED BY Merr_p(k) AND Ferr_p(k)
S820
S816
no
REPEAT UNTIL k REACHES Tcurr, STARTING FROM ZERO.
S814
∞
IS CHARACTERISTIC AMOUNT OF EACH OF TIME SERIES OF ΔMerr(k) AND ΔFerr(k) WITHIN PERMISSIBLE RANGE?
yes
LEAVE REPETITION LOOP.
ΔMerr(k)=Merr(k)−Merr_p(k)
ΔFerr(k)=Ferr(k)−Ferr_p(k)
S824
Merr_p(k)=Merr(k)
Ferr_p(k)=Ferr(k)
S826
k = k + Δk
S828
RETURN

FIG.19

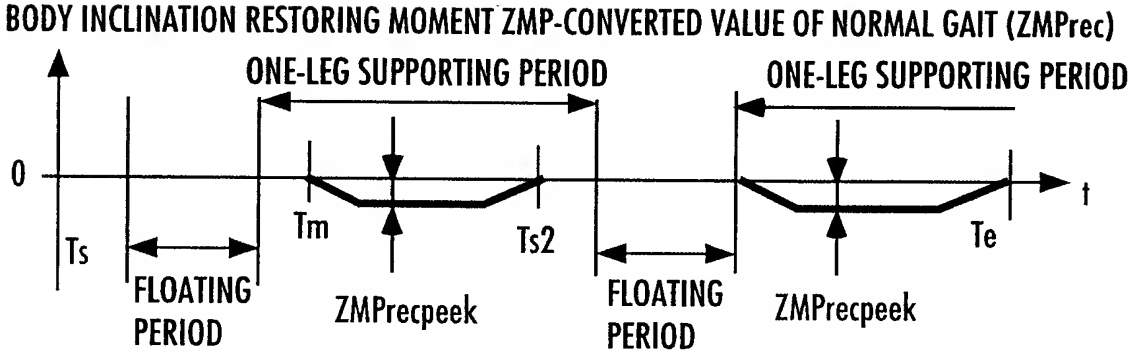

BODY INCLINATION RESTORING MOMENT ZMP-CONVERTED VALUE OF NORMAL GAIT (ZMPrec)
ONE-LEG SUPPORTING PERIOD
ONE-LEG SUPPORTING PERIOD
0
t
Ts
Tm
Ts2
Te
FLOATING PERIOD
ZMPrecpeek
FLOATING PERIOD
ZMPrecpeek

FIG.20

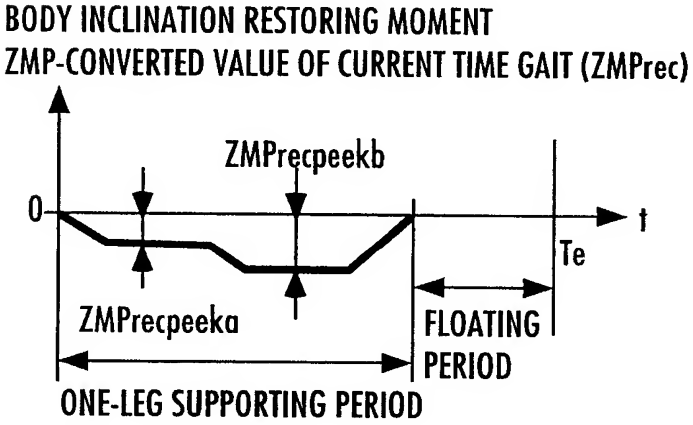
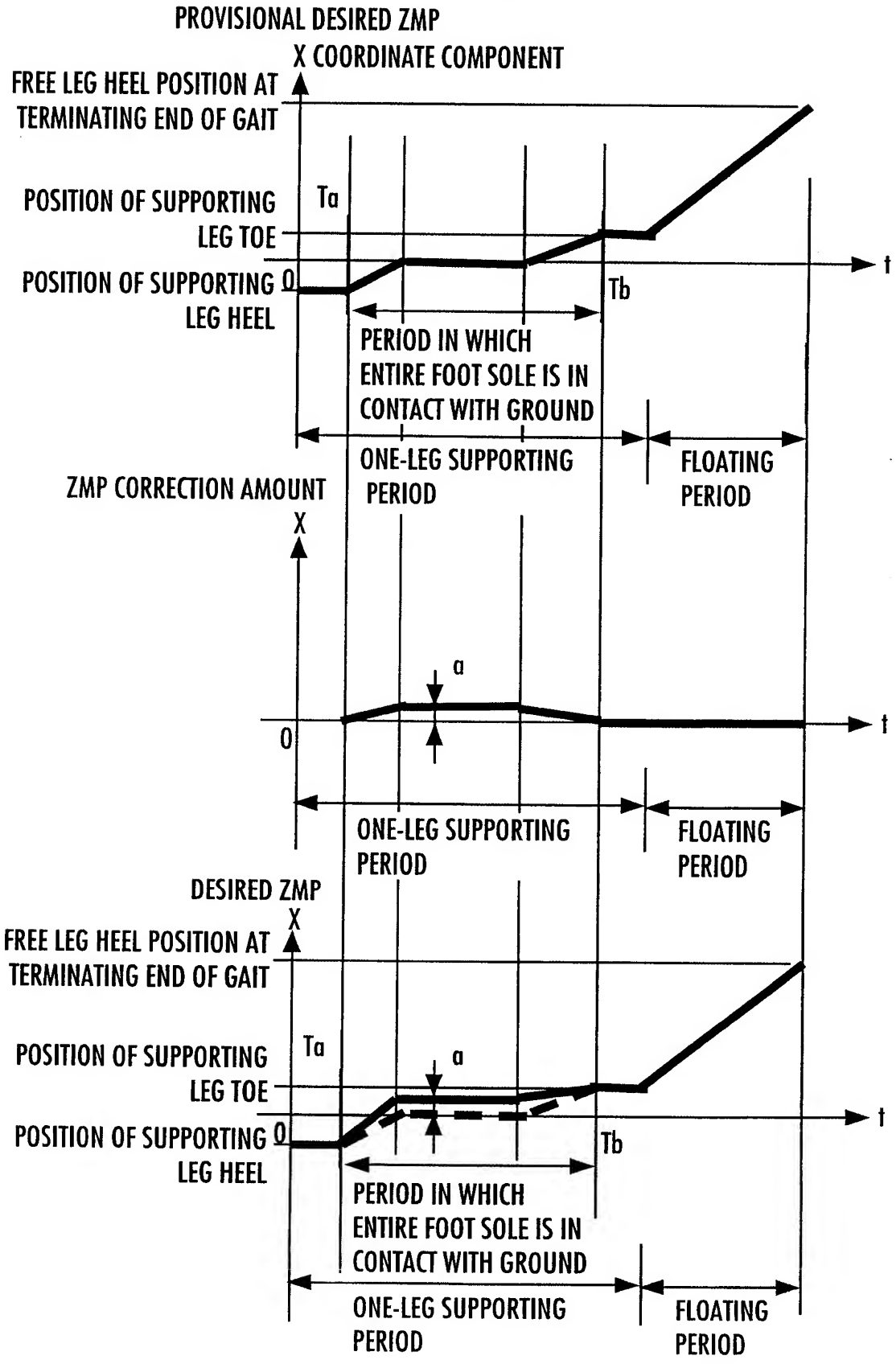

BODY INCLINATION RESTORING MOMENT
ZMP-CONVERTED VALUE OF CURRENT TIME GAIT (ZMPrec)
ZMPrecpeekb
0
t
Te
ZMPrecpeeka
FLOATING PERIOD
ONE-LEG SUPPORTING PERIOD

FIG.21


PROVISIONAL DESIRED ZMP
X COORDINATE COMPONENT
FREE LEG HEEL POSITION AT TERMINATING END OF GAIT
POSITION OF SUPPORTING LEG TOE
POSITION OF SUPPORTING LEG HEEL
Ta
Tb
0
t
PERIOD IN WHICH ENTIRE FOOT SOLE IS IN CONTACT WITH GROUND
ONE-LEG SUPPORTING PERIOD
FLOATING PERIOD
ZMP CORRECTION AMOUNT
X
a
0
t
ONE-LEG SUPPORTING PERIOD
FLOATING PERIOD
DESIRED ZMP
X
FREE LEG HEEL POSITION AT TERMINATING END OF GAIT
POSITION OF SUPPORTING LEG TOE
POSITION OF SUPPORTING LEG HEEL
Ta
a
Tb
0
t
PERIOD IN WHICH ENTIRE FOOT SOLE IS IN CONTACT WITH GROUND
ONE-LEG SUPPORTING PERIOD
FLOATING PERIOD